

Contribution of Images ETM and GIS for the Detection of Dynamic Changes in Steppic Space in the Wilaya of Naama Under the Combined Effect of Climate Change and Socio-Spatial Mutations

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ABSTRACT

This paper highlights the contribution of landsat images to the dynamic monitoring of the steppe area in the high Oran plains (Algeria). The qualitative and quantitative analysis of the rapid evolution of the landscape and especially the silting up in the cities demonstrate an interesting measurement which allows making a provisional assessment of the current state of the study area. This analysis will raise awareness among the population; the local elected officials and the decision maker about the extent of the sanding phenomenon.

By using this analysis, the changes in surface condition between 1957 and 2002 which extracted from different images of Lands at MSS, TM and ETM+had been done. Consequently, three methods of detection of changes (rapid identification and quantification of changes, multirate colored composition technique and dynamic soil cover index techniques) were used to locate the different zones where underwent deep mutations, the special extension of the silting up and the degradation of the grounds inside the regions of the wilaya of Naâmaregion. It is important to note that we used the Olsson model for atmospheric corrections of images.

This study is conducted in the high Oran plain which is administratively attached to the wilaya (department) of Naâma. It covers an area of 29,825 km², between 32°08' and 34°16' north latitude and 0°09' and 1°43' west longitude. The use of remote sensing data through the dynamic soil covers index and the diachronic color-composite images allowed focusing the different changes that took place from 1987 to 2002.

These changes which concern the changes in the ratio of landscape units in the steppe zone necessitate testing several indices of change (vegetation index, gloss index, curass index and principal component analysis) to minimize errors in the assessment of results of these changes.

It is well known that the remote sensing for the result of dynamic changes is influenced by cyclical variations (season, weather conditions). Therefore the radiometric and atmospheric corrections to the images are necessary. Emphasis was placed on the processing of diachronic remote sensing data for the monitoring and development of silting in an arid environment concerning the southwestern part of the high Oran plains.

In fact, this analysis revealed that for the entire study region, the surface silted areas increased from 1.38% in 1957 to 42.9% in 2002 or an area of 1,280,762 ha; which corresponds to an extension of 28,461.4 ha per year. It is important to note that the diachronic study involved delicate phases, in particular the choice of the mathematical model for the atmospheric correction (absolute or relative) of the satellite images as well as the determination of the parameter of

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Received: July 01, 2020; **Accepted:** July 15, 2020; **Published:** July 22, 2020

Citation: Abdelkrim B, Mohamed A, Tewfik M, Rachid N (2020) Contribution of Images ETM and GIS for the Detection of Dynamic Changes in Steppic Space in the Wilaya of Naama Under the Combined Effect of Climate Change and Socio-Spatial Mutations. J Remote Sens GIS. 9:276. DOI: 10.35248/2469-4134.20.9.276

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the real reflectance of the soil for the test samples. This parameter requires adequate equipment (spectroradiometer) or a database on the absolute reflectance of objects. Also, in this study it is recognized that the indices are not very effective for detecting change in an arid zone where the characteristics of the soil and the presence of sand considerably influence the spectral aspect of objects.

Keywords: Change detection; Sanding up; Remote sensing; Naama

INTRODUCTION

The detection and identification of changes appear on the surface of the earth which is one of the essential concerns for managers and scientists who involve in the understanding and managing of natural and artificial ecosystems [1]. In recent years, it has been witnessed a real dynamic change in the steppe with the advance and extension of the silting up towards the interior of the country. Indeed, the harmful effects of periods of drought from the 1970 s combined with the increase in population (under the effect of socio-political constraints) also the economic situation of the country in the 1990's completely and strongly changed the fragile balance of the arid steppe environment.

These effects largely contribute to the partial or total disappearance of the steppe routes (irreversibility) and certain parts of the national reserves which contained the wilaya of Naâma (Haoud ed Deïra, Chottchergui, chottRharbi and the oases of Mogharrar and Tiout classified RAMSAR site) [2]. However, the spatial planning specialists and local officials fully understand the different socio-spatial mutations that affect the southwest steppe of the 'Algeria due to the location in space and time of the most different sectors which significantly change. Moreover, in a steppe environment, the evaluation of the extent of the changes will certainly help to better understand the process of silting and the regression of grasses (*Stipa tenacissima*, *Artemisia herba Alba* and *Lygeumspartum*) in their spatiotemporal dimension.

At the level of our study area, field data concerning the phenomenon are scarce. However, if they exist, they do not allow presenting the process of silting in a synoptic vision.

Most of the scientific work that exists focuses on restricted areas while the phenomenon requires multi-scalar approaches (supranational, regional and local scales).

In this respect, the use of remote sensing data is essential to draw up reliable assessments and hypotheses on the degradation of the routes and the installation of dune buildings. In this context, images of satellite and multidata establish an excellent source of information. However, they remain insufficiently exploited for the evaluation of the dynamics of steppe areas [2].

The land use map is necessary but insufficient document for understanding the rapid evolution of the phenomenon of soil degradation and the movements of the dunes. Regular monitoring of this phenomenon over long periods using satellite imagery can better assess the mechanism of dune evolution on steppe rangelands. The regular estimation (annual) of the transformation of an environment makes it possible to draw curves which illustrate the trend of the evolution of the phenomenon [3]. Therefore, it is possible to predict future

developments in natural phenomena and establish a calendar for the acquisition of images according to the speed of development of the silting up.

The construction of land use maps for the years 1972, 1987 and 2002 is therefore not necessary since it requires sampling missions for the years concerned or at periods close to them, at any way the state of the trails presents a situation analogous to that existing at the time of the shooting.

PRESENTATION OF THE STUDY AREA AND METHODOLOGY

The geographic setting

This study is conducted in the high Oran plains which administratively attached to the wilaya (department) of Naama. It covers an area of 29,825 km², between 32°08' and 34°16' north latitude and 0°09' and 1°43' west longitude. The pilot area extends from ChottChergui to the north, branch of the Ksour Mountains chain (Saharan Atlas) to the south. From west to east, it covers the space between the small reliefs close to the Algerian-Moroccan border (Djebel Gaaloul, 1613 m) and the eastern limit of the wilaya of El Bayadh. They can be some morphological units. Moreover, the territory of the wilaya consists of an immense plain which is confined between the two Atlas (Figure 1). This landscape monotony is broken by a few mountain ranges oriented south-west north-east. The example of the alignment of the djebel Gaaloul (1613 m) is cited which is extended to the north by the djebels El Arar (1801 m) and Kerrouch whose continuity to the northeast is with the djebel BouRhenisa (1594 m) to finish further north by djebel Antar which culminates at 1721 meters above sea level.

On a climatic level, the aridity of the climate has increased. Mécheria station has been moved from the upper arid stage in cool winter to the lower arid stage in cool winter. Likewise, Ainsefra has changed from the arid stage below in cold winter to the arid stage below in cool winter [4]. Similarly, the rainfall during the period (1978-2001) decreased compared to the period of (1913-1938) the deficit fluctuates between 19% and 33% for Ainsefra and Mécheria respectively. In addition, climate analysis has revealed that in Mécheria, 83% of annual precipitation is below the average annual value of the period (1913-1938) [3]. The annual average rainfall for the period 1970 to 2001 is 180.7 mm in Mécheria with 57 days of rain. It is 214 mm with 58 days of rain, and 155,5 mm with 38 days of rain respectively in Naâma (1990 to 2001) and Ainsefra (1978 to 2001) [4].

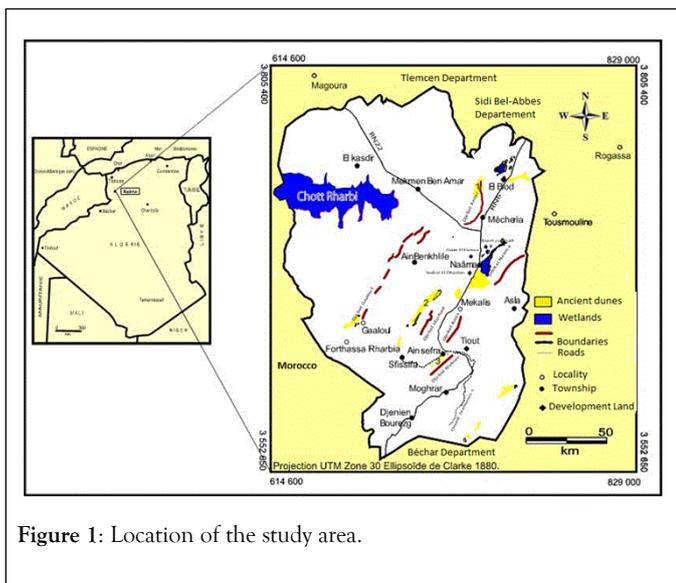


Figure 1: Location of the study area.

Methodology

The methods for the detection of change are generally submitted to various levels of constraints: radiometric and spatial. The conditions of lighting and atmospheric attenuation are very variable in time and space. Therefore the images require radiometric and atmospheric corrections, to standardize the multispectral data of the multidata images used. Finally, it is important that the images are also geometrically corrected [5].

Several methods of detecting of changes in land use have been used. They are based on the comparison of six TM and ETM +scenes from Landsat. It is important to note that the three MSS scenes from 1972 have spectral and spatial defects. This constrained the researcher to not build the mosaic to cover the entire area and prepare a multi-date comparative analysis. The Scenes 212/37 and 213/37 are not juxtaposed. However, they were used in the rapid analysis of the evolution of the environment. This analysis is based on the interpretation of the different multidata images. Before applying the methods for the detection of change which affect the environment, the images sustained geometrical, radiometric and atmospheric improvement treatments. The different methods that have been implemented (Figure 2).

Table 1: Characteristics of the MSS, TM and ETM+images of the study area.

Images	MSS			TM and ETM+		
	MSS CCT FORMAT			ETM+ and TM CCT FORMAT		
Satellites	Landsat 1			Landsat 5 et Landsat 7		
Image center	212/37	213/36	213/37	197/37	198/36	198/37
Total dimension	3512*3310	3512*3310	3512*3310	5761*7020	5761*7020	5761*7020
Date	11/15/1972	11/16/1972	01/29/1972	04/25/1987 02/16/2002	03/31/1987 01/27/2002	03/31/1987 03/13/2002

In this study area, the detection of significant changes in land use required the following steps:

1. Selection of multidade multispectral images;
2. Choice of the reference image;
3. Radiometric correction of TM and ETM+images;
4. Geometric correction of MSS, TM and ETM+images;
5. Methods of detecting of changes:

Rapid identification and quantification of the evolution of changes;

Multidade coloured composition technique;

Dynamic soil cover index.

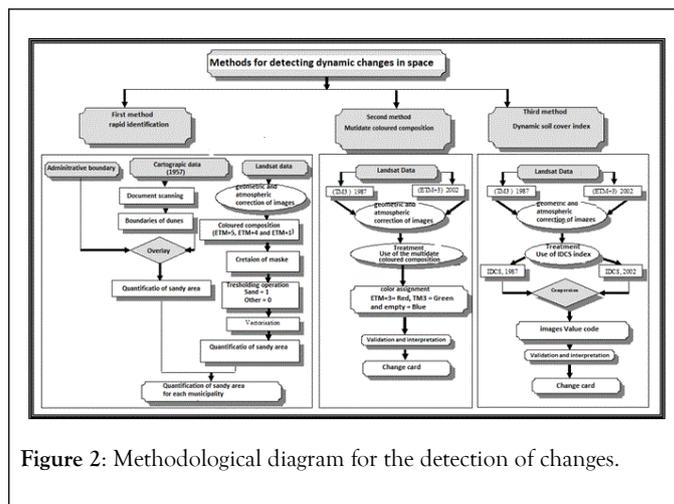


Figure 2: Methodological diagram for the detection of changes.

Data used

For this study, there are nine multidata scenes from the Landsat satellite (ETM+,TM and MSS) plus topographic maps from 1957 were used to analyze the spatial dynamics of sandy accumulations over a period of 45 years. The characteristics of the scenes used (Table 1).

Shooting time	10 hr 06	10 hr 00	10 hr 02	09 hr 56	10 hr 00	10 hr 01
Latitude in degree	33.1	34.5	33.1	33.2	34.61	32.2
Longitude in degree	-0.2	-0.8	-1.2	-0.2	-0.91	-1.3
Processed dimension	3512*3310	3512*3310	3512*3310	5761*7020	5761*7020	5761*7020
Zenithal angle in degree	55.89	52.35	60.36	32343(b0)	59.04 (2002)	41.3 (1987) 43.76 (2002)
Elevation (degree)	34.11	32.65	29.64	-	30.96 (2002)	48.70 (1987) 46.24 (2002)
Azimutal angle (degree)	152.89	153.74	143.05	120.25 (1987) 146.09 (2002)	149.57 (2002)	128.66(1987) 140.11 (2002)

Radiometric and atmospheric correction

In remote sensing, the information about the earth’s surface is electromagnetic radiation. The Satellite measurements are made at the level of the sensor on board a satellite, are generally very difficult to exploit in an image interpretation process, since the properties of the radiation are disturbed by the atmosphere during the double path: sun-earth and earth-sensor [6].

The propagation of the signal in the atmosphere and the specific characteristics of the sensor introduce a distortion in the radiometric measurement. The cloud cover difficulty returns the acquisition of measurements which regularly distributed over time.

In a multirate study where a regular dynamic monitoring of a phenomenon by remote sensing, it is appropriate to correct the radiometric images, because they are taken under very different shooting conditions (solar lighting, calibration coefficient, zenith angle, azimuth angle, etc.) which change over time.

The correction of radiometric and atmospheric aim to minimize these disturbances caused by the atmosphere, and to determine the true spectral response which received by the satellite, of the target. For this purpose, radiometric and atmospheric correction models are made for:

A multi temporal study, in order to put all the images in the same radiometric reference frame, which makes it easy to detect the real changes that have taken place between the different dates;

Achieve absolute measurements to monitor the dynamics of a given phenomenon;

Improve the automatic classification process.

Principle of the absolute model of using radiometric correction: The radiometric and atmospheric are developed by a model [7]. This model takes into account the variations induced by the atmosphere and the shooting conditions. It is used to correct the differences induced by the angle of the sun, the atmosphere and to calculate the reflectance of the object at ground surface.

This absolute calibration model is based on the using and selecting of invariant common areas (test samples) which are extracted from a zoning of pixels common

The average of each sample is used to determine its luminance at the level of the sensor according to the equation 1:

$$L_{sat} = L_{min}(\lambda) + \frac{L_{max}(\lambda) - L_{min}(\lambda)}{V_{max}} CN \quad (1)$$

Where: L_{sat} is the apparent luminance measured by the sensors on board of the satellite; L_{min} and L_{max} are maximum and minimum luminance values of each sensor; CN is the digital count of each pixel of the image, $V_{max}=255, 127$ or 63 depending on the numerical values is used on (8,7 and 6) bits.

But the estimation of the reflectance value for each sample at ground level is considered the most important thing. But the most important thing to achieve is to estimate the reflectance value of each sample at ground level. This reflectance requires either the use of a field radiometer or spectroradiometric curves which is manufactured in specialized laboratories. These curves are generally specified in the bibliography form as graphs. To extract the value of the reflectance from the graph, it is enough to know the value of the wavelength of the sample in each image. Likewise, if the radiometer is used in the field, it will be calibrated for each measurement which is carried out in the field inside each test zone.

According to the model of Olsson the absolute reflectance of an object is given by the equation 2:

$$R_{sol} = \pi \frac{L_{sol}(\lambda)}{E_s \cos(\theta_s) T} = \pi \frac{(L_{sat}(\lambda) - L_{atm}(\lambda))}{E_s \cos(\theta_s) T} \quad (2)$$

Equations (1) and (2) can be combined by a simple expression to convert the pixel of the Digital Count (CN) into absolute reflectance. Indeed, we get equation 3:

$$R_{sol} = \alpha + \beta CN \tag{3}$$

avec:

$$\alpha = \pi \frac{(L_{min}(\lambda) - L_{atm}(\lambda))}{Es \cos(\theta_s) T}$$

$$\beta = \pi \frac{(L_{max}(\lambda) - L_{min}(\lambda))}{Es \cos(\theta_s) T \cdot V_{max}}$$

Where:

CN_j: Value of the pixel measured in a band for the pixel j

R_{satj}: Absolute reflectance for pixel j

L_{sol}: Spectral luminance of the object measured at ground level (w.M².sr⁻¹. μ m⁻¹)

L_{sat}: Spectral luminance of the object measured at the satellite level (w.M².sr⁻¹. μ m⁻¹)

L_{atm}: Atmospheric luminance (w.M².sr⁻¹. μ m⁻¹)

Es: Solar constant (irradiance) in (w.M². μ m⁻¹)

T: Total transmittance which is given by the following formula

$$T = \frac{1}{1 + \frac{b\tau}{\cos(\theta_s)}} \quad \text{et} \quad b\tau = 0.5 \tau_r + 0.16 \tau_p \tag{4}$$

avec :

$$\tau_r = \tau_0 [1 - \exp(-z/8)] \quad \text{et}$$

$$\tau_p = \exp(-2v/30) \quad C(\lambda)$$

or:

τ_r: Factor relating to Rayleigh's molecular diffusion ;

τ_p: Factor relating to the diffusion by aerosols of MIE;

τ₀: Represents the optical thickness of Rayleigh for the whole atmosphere, it is given by the following formula:

$$\tau_0 = (84.35 \cdot 10^{-4}) \lambda^{-4} + (1.225 \cdot 10^{-4}) \lambda^{-5} + (1.4 \cdot 10^{-4}) \lambda^{-6}$$

z: is the altitude of the aerosols expressed in km

C(λ): is a wavelength function, it is given by:

$$C(\lambda) = 0.632 \lambda^{-1} - 0.02 \lambda^{-2}$$

V: Represents the visibility expressed in km.

L_{min}, L_{max}: Maximum and minimum luminance values.

θ_s: solar zenith angle.

The parameters (L_{min}, L_{max}, Es and θ_s) of the model are obtained from the header files of each image.

Validity of the model using Multidate images: The coefficients α and β of the model have been calculated, which allow the

passage of a digital count (CN) of a pixel in real reflectance data of the ground. The estimation of these two parameters of the model was carried out by choosing the samples representing of objects invariant in time from the images of the six scenes between the period of 1987 and 2002 [5]. The choice is defined so that the sample selection on the image of each scene in 1987 must be the same on the image of the period in 2002. These two samples will be used only for the determination of the atmospheric luminance (Latm). The latter is evaluated using equation 5:

$$L_{atm} = L_{sat} - L_{sol} \times T \tag{5}$$

The luminance L_{sat} is deduced from equation (1), however L_{sol} is estimated from existing spectroradiometric curves in the Teravue software database. These curves help us to select sand and bare soil to record their actual reflectances measured at ground level in the wavelength range of the Landsat TM and ETM+ sensors.

Once the luminance L_{sol} has been calculated, the luminance L_{atm} is deduced directly from equation (5). Then, a L_{atm} average is calculated for two samples for atmospheric correction of all the images using the model of Olsson. The result for the calculation of α and β is illustrated in Table 2.

Table 2: Coefficients α and β of the atmospheric correction model for Landsat TM and ETM+ images.

path and row of scenes	2002 ETM images					
	197/37		198/36		198/37	
Coefficients α and β of the model	β		β		β	
ETM1	0.0413	0.0013	0.026 5	0.00 22	0.009 1	0.001 9
ETM2	-0.046 7	0.002	-0.031 1	0.00 35	-0.04 81	0.002 7
ETM3	-0.1318	0.002	-0.093 9	0.00 36	-0.109 4	0.002 6
ETM4	-0.1992	0.0031	-0.143 1	0.00 37	-0.07 54	0.002 6
ETM5	-0.1551	0.0028	-0.106 6	0.00 33	-0.010 5	0.002 4
ETM7	-0.229 5	0.003	-0.211 4	0.00 35	-0.133 1	0.002 5
path and row of scenes	1987 TM Images					
	197/37		198/36		198/37	
Coefficients α and β of the model	β		β		β	

ETM1	0.0594	0.0007	0.0367	0.0009	0.0231	0.0009
ETM2	-0.0222	0.0022	-0.0181	0.0026	-0.0361	0.0026
ETM3	-0.1073	0.0021	-0.0772	0.0023	-0.1015	0.0023
ETM4	-0.1915	0.0032	-0.1185	0.0023	-0.1025	0.0033
ETM5	-0.1476	0.0022	-0.0808	0.0002	-0.0013	0.002
ETM7	-0.212	0.0029	-0.1967	0.0033	-0.1599	0.0031

For the validity of the atmospheric correction model, a comparison was made between the absolute reflectance values which calculated from the model of two-sample test for 1987 and 2002. A variation of absolute reflectance is relative to each sample of less than 1% was obtained (Table 3).

This result can only confirm the performance of the model in rectification of radiometric disturbances and atmospheric satellite Image.

The low variation in the measurement of the reflectance of the objects for each scene reinforces the quality of the processing which carried out on the images to detect changes between the two dates.

Table 3: Estimation of the absolute reflectance of two samples (sand and bare soil).

	Sand sample								
	197/37			198/36			198/37		
	Absolute reflectance in (%)			Absolute reflectance in (%)			Absolute reflectance in (%)		
Years	1987	2002	(-)	1987	2002	(-)	1987	2002	(-)
ETM 1	10,51	10,31	-0,20	9,95	9,29	-0,66	9,48	10,53	1,05
ETM 2	20,42	19,64	-0,08	17,39	17,27	-0,12	17,39	17,50	0,11
ETM 3	36,51	36,13	-0,38	32,15	31,70	-0,45	32,38	32,31	-0,07
ETM 4	47,51	46,79	-0,72	41,20	41,28	0,08	26,44	26,72	0,28
ETM 5	54,87	53,89	-0,98	49,28	49,68	0,40	34,13	34,37	0,24

ETM 7	53,71	53,03	-0,68	53,67	53,02	-0,65	52,87	52,95	0,07
Bare ground sample									
ET M1	11,93	11,72	-0,20	10,04	10,85	0,81	13,22	13,50	0,28
ET M2	22,19	22,05	-0,14	19,19	19,39	0,20	22,79	23,45	0,66
ET M3	37,62	37,31	-0,31	32,15	32,77	0,62	36,78	36,26	-0,52
ET M4	48,06	48,35	0,29	42,18	42,37	0,19	45,01	45,10	0,09
ET M5	53,89	55,15	1,26	49,68	50,67	0,99	48,98	48,19	-0,79
ET M7	52,44	52,53	0,09	49,43	49,18	-0,25	43,04	43,17	0,13

After Atmospheric normalization, an image processing phase allows defining the zones of change in the Naâma region. For this reason a program in C language has been developed. It allows an automatic rectification of satellite images based on the principle of the model described above as well as on the use of another relative model.

Resampling of satellite images

The purpose of resampling spatial images is to bring them back to the same spatial resolution. In our case, the MSS images (57 m resolution) were resampled at the same resolution as that of the TM and ETM+images (30 m resolution). This step is used to facilitate the visual interpretation of MSS images and the detection of potential changes.

Geometric correction

Geometric correction consists of geometric rectification an image with respect to another (reference) so that the ground element has the same coordinates on the two images. Fourteen points of support were selected for the rectification of each scene. Indeed, all the images are corrected to the reference images (scenes ETM+from 2002). The latter have been rectified to topographic maps with the Clarke 1880 Elliptical UTM zone 30 cartographic projections. The mean standard deviation (RMS) obtained at the end of treatment is around 0.53.

Methods for detecting dynamic changes in space

Once the geometric and radiometric corrections of the geometrically and radiometric satellite images were made, several approaches were applied based on the use of multirate data (MSS of 1976, TM of 1987 and ETM+of 2002) for the detection of changes. The principle of these approaches differs from one method to another.

Rapid identification and quantification of the significant evolution of the extension of the silting up between 1972 and

2002: The qualitative and quantitative analysis of the rapid evolution of the landscape and especially the silting up in the cities demonstrate an interesting measurement which allows making a provisional assessment of the current state of the study area. This analysis will raise awareness among the population; the local elected officials and the decision maker about the extent of the sanding phenomenon.

Before starting this work of rapid dynamic analysis of the environment, some difficulties in determining and knowing the reference state of the environment of the study area were faced. Indeed, it is not possible to assess the state of degradation of the environment and the silting up if we do not refer to a previous state or to initial conditions. The only way to find out the state of reference is to search for ancient and historical documents. However, in most cases these documents do not exist.

At this stage, the only reference documents collected date from the 1950's: the aerial photos of the IGN, the geological and the topographic maps. Since then, the four topographic maps at a scale of 1: 200,000 have been scanned and georeferenced in an international system (UTM zone 30, Clarke 1880 ellipsoid) before being integrated into the GIS (ArcGis). Then a phase of digitization of the sand buildings appearing on the four maps was carried out. The vector file thus obtained was in turn cross-referenced with the file of administrative boundaries in order to establish a quantification of the areas covered with sand within each city

After establishing the reference file for the sandy areas, the wind dynamics were studied using recent ETM+satellite images from Landsat. These images have undergone several image processing operations with a view to their exploitation, in particular:

geometric correction of the images in order to make them superimposable on the already scanned topographic maps;

establishment of a colored composition (ETM+5, ETM+4 and ETM+1) and application of a mask (administrative boundary) to ignore the areas located outside the administrative boundaries;

Creation of a binary image where only the sand theme appears; the other themes have been hidden to avoid any confusion between them during processing. However, this technique is delicate insofar as it requires a certain precision in the definition of the range of extreme values which limit the sand theme. An error in the definition of the interval could influence the result on the quantification of the sandy areas. In this respect, the verifications on the limits of the sandy areas based on a few aerial photographs were necessary. In addition, to make the processing result properly acceptable, a morphological filter (dilation) was applied to the binary image in order to eliminate the isolated pixels and to make the structures of the sand element more homogeneous;

Direct digitization on the computer screen of the limits of the silted areas;

Vectorization and cross-referencing of the file with the administrative limits;

Finally, quantification of the sandy areas for each city is established using a spatial request made on the file *via* SQL language.

The result of these treatments are shown in Table 4. However, according to the result of 1950's, the sandy areas inside each city didn't exceed 6% of the total city area. While, in the cities of DjenienBourezg, Kasdir, Mekmen Ben Amar, Mécheria and Tiout, the area of sandy areas is almost zero. The largest extension is located in the city of Naâma and El Biod with a percentage varying respectively from 2.42 to 5.77% of the total city area. In 1957 the total area covered with sand represents a percentage of 1.38% compared to the total area of the wilaya.

Conversely, recent images from 2002 have shown an alarming development in the spread of sand, particularly in the city of the northwest (Ain Benkhelile, Mekmene Ben Amar, El Biod, Naâma, Kasdir and Mécheria). The city of Mekmene Ben Amar is the most affected by the silting up where the surface of the sanded areas is around 78.78% of the total area of the city. For the region as a whole, the area of sandy areas increased from 1.38% in 1957 to 42.94% in 2002; which corresponds to an extension of 28,461.4 ha per year. This number is considerable and it shows the extent of the phenomenon.

This analysis allowed us to see the extent of the sandy area (1280762 ha) which corresponds to almost half of the area of Belgium, and above all, the speed of propagation of the silting is 28 461.4 ha per year. However, for this method there are difficulties in defining the limits of the silted areas. To this end, several tests have been carried out to better highlight the sand inside the wilaya.

Table 4: Evolution of sandy areas for the period 1957-2002 in the Naâma region.

Township	Township areas in hectare	Period of 2002		Period of 1957	
		Sandy area in hectare	Sandy area in (%)	Sandy area in hectare	Sandy area in (%)
Ain Ben Khelile	383248,00	252977,04	66,01	6606	1,72
Ainsefra	103209,00	37361,62	36,20	1955	1,89
Asla	208167,00	14768,44	7,09	3005	1,44
Djenien-bourezg	118265,00	2543,13	2,15	0	0,00
El Biod	371625,00	133300,00	35,87	8983	2,42
Kasdir	645110,00	275254,00	42,67	0	0,00

Mécheria	75859,60	44806,15	59,06	0	0,00
Mekemn Ben Amar	326264,00	257025,75	78,78	0	0,00
Moghrar	184226,00	6878,06	3,73	1774,43	0,96
Naâma	251802,00	154251,43	61,26	14525,48	5,77
Sfissifa	235058,00	84943,39	36,14	4244,05	1,81
Tiout	79716,00	16653,00	20,89	0	0,00
Total	2982549,60	1280762,01	42,94	41092,96	1,38

Trend of rapid evolution: The quantification of the dynamics of the sandy areas which previously carried out allows evaluating the current state of the ground surface. However, this quantification must be placed in a temporal context.

The dynamic analysis is insufficient to highlight the kinematic vision of the phenomena and also to know their evolutionary trends [7].

However, with the help of a series of curves, we can understand the trend of silting up within each administrative boundary. This will allow us to know the date of the beginning of the phenomenon as well as the rapidity of its spatial propagation.

This information is very useful insofar as it will allow, by combining it with other information (rainfall, period of drought, extension of the useful agricultural area, the developments already carried out, evolution of the livestock, etc.). It helps to understand the causes of the extension of the phenomenon to the space-time scale.

Similarly, the geometric shapes of the trend curves characterize the dynamics of the phenomenon for each city, for example, a linear trend characterizes a regular dynamic movement of wind erosion (progression of the silting up as the vegetation regresses), and on the other hand an exponential trend indicates a progression of the phenomenon which increases with time (Figure 3).

Table 5: Evolution of the silting up in the wilaya of Naâma during the periods of 1957, 1972, 1987 and 2002.

Township	Total Township areas in hectare	Sandy area in hectare 1957	Sandy area in hectare 1972	Sandy area in hectare 1987	Sandy area in hectare 2002
Ain Ben Khelile	383248,00	6606	37144,00	161307,9	252977,04
Ainsefra	103209,00	1955	9429,00	21246,18	37361,62
Asla	208167,00	3005	6267,79	8072	14768,44
Djenien-bourezg	118265,00	0	0,00	0	2543,13

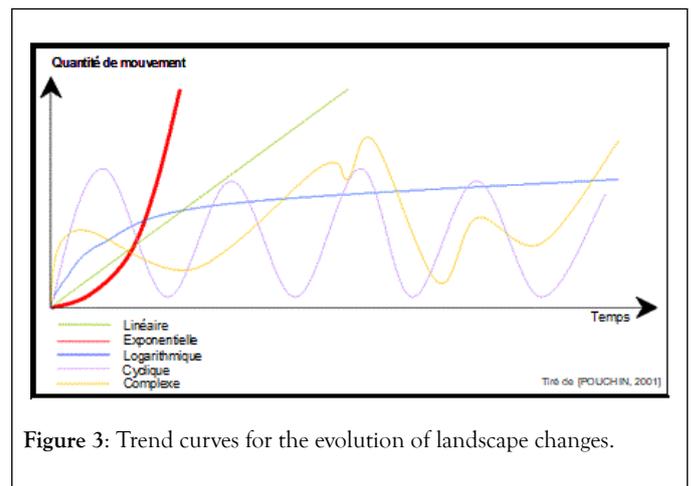


Figure 3: Trend curves for the evolution of landscape changes.

For the whole wilaya and for each city the sandy areas was estimated due to the treatments which carried out the recent multi-date images (1972, 1987 and 2002) of MSS, TM and ETM + of Landsat and the topographic maps of 1957. It would be noted that the evaluation of the sandy areas is carried out automatically using geographic information systems for all the years of the time series (Table 5).

Since the graphics have been made in order to have a kinematic vision of the phenomenon of silting up for each city. Indeed, it is clear from Figure 4 that the evolution of sandy areas has shown an increasing trend since 1972.

In addition, the most significant evolution still concerns the regions of the North West of our study area. But the important thing to see is the date of the beginning of the phenomenon compared to the reference date of 1957. also, it was found that in the 1970's the change in the phenomenon was almost imperceptible on the MSS images of Landsat of 1972, apart from the old dunes which already appeared in the reference documents (topographic maps and the geological map at 1: 500,000) as well as the two city are located north of the wilaya (El Biod and Mekmene Ben Amar). At that date, the siltation concerned 6.73% of the total area of the wilaya. However, with the limited image data available, it is important to determine with greater precision the true date of onset of the phenomenon. This would require the use of several images at least one image per year, which is impossible for our study.

El Biod	371625,00	8983	76904,00	102986	133300,00
Kasdir	645110,00	0	2693,55	64336,4	275254,00
Mécheria	75859,60	0	371,22	11125,4	44806,15
Mekemn Ben Amar	326264,00	0	27084,20	165747,6	257025,75
Moghrar	184226,00	1774,43	2881,00	3260,25	6878,06
Naâma	251802,00	14525,48	25577,00	143511	154251,43
Sfissifa	235058,00	4244,05	6302,20	31161	84943,39
Tiout	79716,00	0	5924,61	8660	16653,00
Total en (ha)	2982549,60	41092,96	200578,57	721413,85	1280762,01
Total en (%)	100,00	1,38	6,73	24,19	42,94

On TM Landsat images from 1987 the phenomenon becomes more noticeable and alarming. During this period, the silting affected 24% of the total area of the landscape concerning the wilaya, i.e. 721,413.59 hectares.

For a period of 15 years (1972-1987) the phenomenon has progressed at a speed of 34,710.33 hectares per year. This increase is 3 times greater than that of the first period (1957-1972) where the speed of progression recorded is of the order of 10644.37 hectares per year.

The dynamics of the area and the increase in the sandy areas inside the wilaya are clearly visible in recent ETM+images from Landsat. Sand and dune buildings are omnipresent in the nomenclature that makes up the steppe landscape. Previously, it was the alfa that dominated the steppe landscape. In all the documents, consulted alfa was present even in the early 1980's. However, with the progression of sand the alfa disappears and it is replaced by other taxonomies which support the arid conditions of the environment and the sand. In 2002, an increase of around 20% compared to the second period was recorded. So, for the past 45 years, sand has been gaining ground and each year colonizes 28,461.4 hectares.

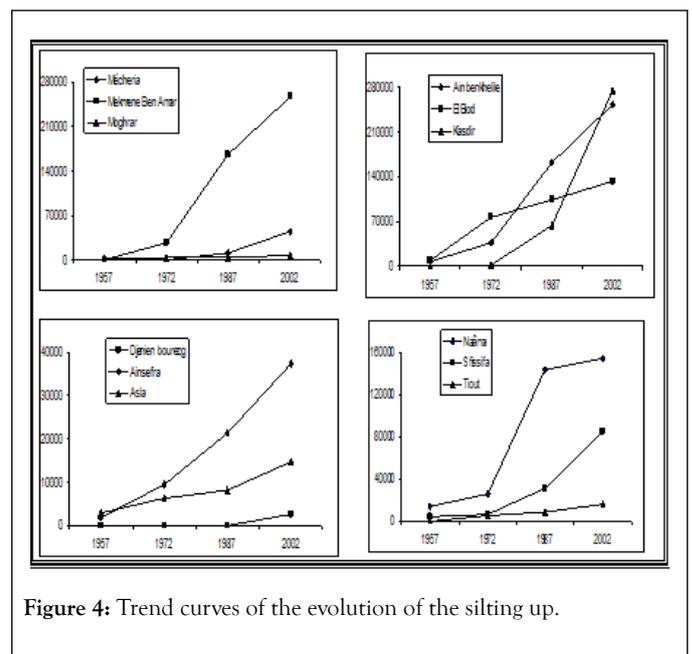


Figure 4: Trend curves of the evolution of the silting up.

The trend curves in Figure 4 show that the phenomenon clearly increases over time. According to these trend curves, the phenomenon is much more accentuated in the city of north, north-eastern and north-western. The cities of south display a linear progression and less significant to the other cities. This is due to the fact that the southern communes are protected by the Saharian Atlas Mountains. However, the presence of a few openings between these mountain ranges has not spared certain southern cities, such as Ainsefra and Sfissifa. In addition, the wadis (wadi Sfissifa, wadi Breïdj, wadi Namous and wadi Rhouïba) contribute directly or indirectly to the supply of sand to the areas further south during a torrential downpour (Plate 1).

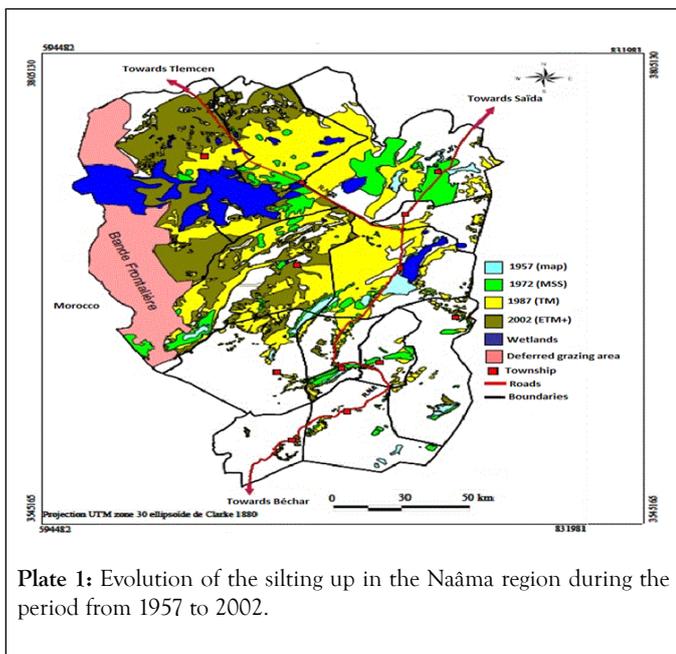


Plate 1: Evolution of the silting up in the Naâma region during the period from 1957 to 2002.

Multidate colored composition technique: In order to identify the major changes that has affected the study area from 1987 to 2002, the use of the multidate colored composition technique. This technique, easy and quick to implement, consists of superimposing different date channels. On this colored composition, the color of the unchanged pixels will be coded in yellow for objects with strong and medium reflectance's (buildings, bare soil, sand, etc.), and in black for weak reflectance's (water, afforestation). As for the pixels which did not have the same reflectance values between the two dates, they will be coded in red and green color more or less saturated according to the size and the extent of the change.

Given the extent and size of the study area, we preferred to show pilot areas that have experienced real changes in the landscape over the past fifteen years.

Indeed, other considerations (date of shooting, geo-referencing error, failure of a shooting instrument, shooting condition, rotation of culture) can generate variations of considerable spectral response which can distort the result of the changes. For this purpose, the use of very high spatial resolution images is recommended. With this type of image, in addition to the color, other parameters are taken into account in particular: the size, the texture, the position and the shape of the object in order to precisely define the category of change [8].

Plate 2 comes from the colored composition of the red channels of the images of 1987 and 2002. The choice of the red channel (ETM+3 and TM3) was dictated by the fact that in the latter, the vegetation is represented by low radiometric values and the mineralized zones are characterized by high values.

Therefore, this strong contrast between vegetation and bare soil undoubtedly favors the highlighting of areas of change affected by human presence.

Plate 3 is made in the same way as the previous one except that it presents another zone inside the wilaya of Naâma. However, the visual interpretation of the two previous plates revealed that

the region has undergone profound changes in recent years. These changes are highlighted by the radiometric modification of the pixels which have undergone a change on their surface.

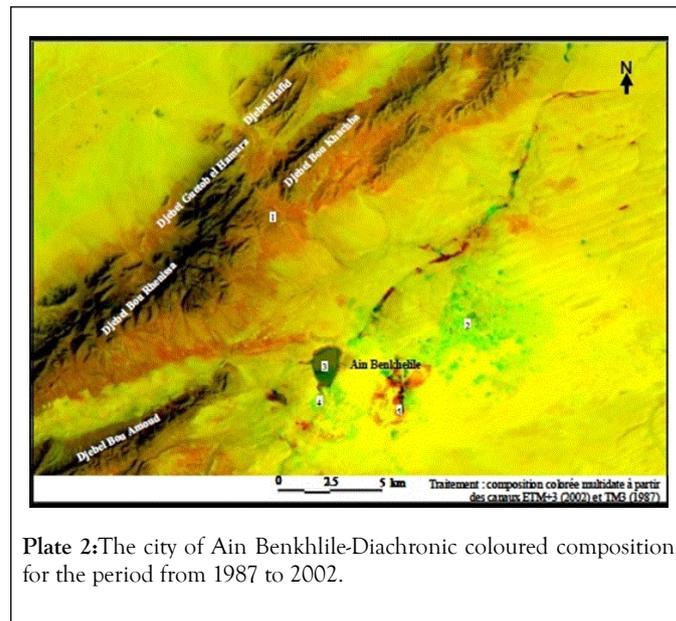


Plate 2: The city of Ain Benkhlile-Diachronic coloured composition for the period from 1987 to 2002.

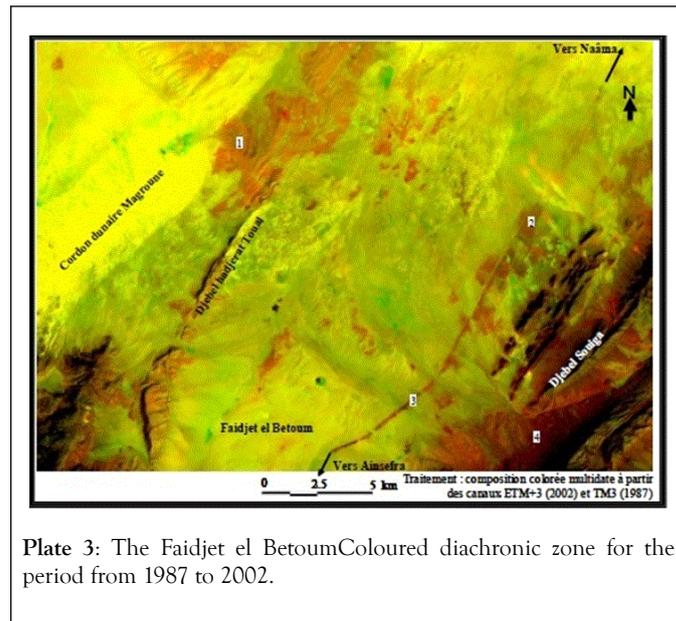


Plate 3: The Faidjet el Betoum Coloured diachronic zone for the period from 1987 to 2002.

The area of Ain Benkhlile in Plate 2 shows the extent of developed land (2) after 1987 that appears (green color). However this area has known a risk of silting up since 1987. On this colored composition clearly appears the progression of the dunes of the west (between djebel BouAmoud and djebel BouRhenissa) and of the northwest (between djebel Hafid, djebel BouKhachba and djebel Guetob el Hamara). On this date the local officials have settled and stem the problem of silting up before starting the execution of the application of the law 83/18 relating to the APFA (Accession to the Land and Agricultural Property) [9]. The red color which appears on the image clearly shows the regression of the vegetation and the progression of the reflectance of the mineralized surfaces. Therefore, the disappearance of vegetation since 1987 has favored the progression of sand towards the regions of the commune of Ain Benkhlile.

After 1987, the glacia with limestone crust and and crusting with *stipa tenacissima* located north of Ain Benkhelile appear in red, more or less saturated (1). This saturation reveals the extent of the degradation of the steppe vegetation or even its disappearance. It can be noted between 1987 and 2002 that the developed land (2) has greatly increased compared to the defensive areas (4) for the development and protection of the site of Oglat ed daïra (3). Moreover, this site benefits from a management plan with a view to its classification as a natural reserve.

The green strip (5) that protects the village of Ain benkhilile which was also declined between 1987 and 2002 despite restoration (reforestation) work by the forest management. This regression is mainly related to human influence (clearing and uprooting of woody trees) as well as the advance of sand [10].

It is important to note that according to the interpretation of the diachronic image, it appears that the restoration works of the sites are only carried out in very limited areas. However, the spatial dimensions of the existing dune buildings in the wilaya, these restoration and reforestation works constitute a threat to the village of Ain benkhilile. In the short term, reforestation using *Tamarix gallica* will stop the advancement of the sand, but in the long term they turn into real sand traps and contribute to the formation of large dunes. This phenomenon is already observed for the green belt which runs along both sides of the national road between Mécheria and Ainsefra [11].

Plate 3 relates to an area located between the city of Naâma and the city of Ainsefra where the progression of the sandy areas and more particularly the dune cord of Magroune in (1) are very clear.

The appearance of these areas in red signifies the progression of mineralized surfaces (sand). The destabilization of the cordon constitutes a real threat for the cities located in the axis of potential displacement of the sand (Figure 5).

Moreover, the farming areas are located by the road in 1987 disappeared and were completely silted up in 2002 in (2). In addition, the red line along the national road (RN6) in (3) shows the silting up of the green belt after 1987. In the 1987 images, the latter appears to be in good condition.

The glacia zone near djebel Souiga experienced the same problem of vegetation degradation observed in the glacia zones located north of Ain Benkhilile. The yellow color illustrates the persistence of the zones during the period from 1987 to 2002.

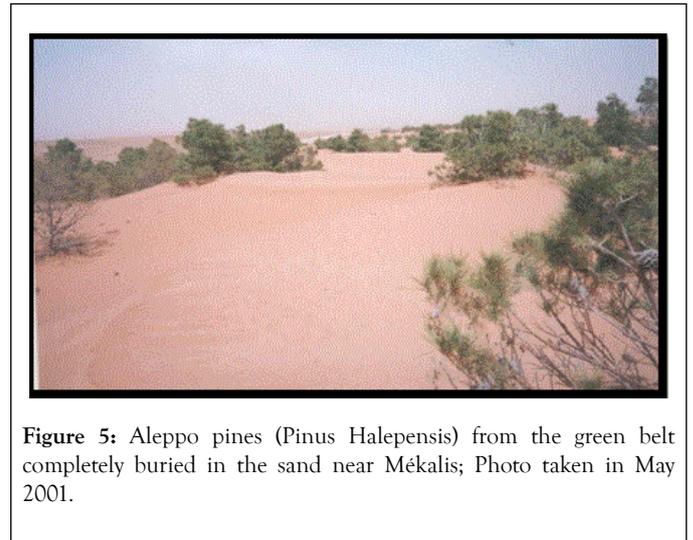


Figure 5: Aleppo pines (*Pinus Halepensis*) from the green belt completely buried in the sand near Mékalis; Photo taken in May 2001.

Dynamic soil cover index techniques: The use of the principle of diachronic coloured composition based on the red channel (ETM+3 and TM3) is a good way to bring out the different mutations of the steppe space on a global scale [4].

However, these changes require a visual interpretation which is based on the principle of the additive color model or subtractive. Therefore, a user not experienced in the field will have difficulty understanding and interpreting the diachronic compound. For this purpose, the use of the Dynamic Soil Cover Index (IDCS) which makes it possible to apprehend the alternations between the soil and the vegetation was preferred. It is important to note that the work was used to practice this dynamic index of land cover [7].

First, the vegetation index, the gloss index, the diachronic principal component analysis and the breastplate index were tested to determine the real changes. Unfortunately, all these indices have given disappointing results, even difficult to interpret.

The use of the vegetation index in arid zones is not recommended, since the spectral response of the vegetation is strongly influenced by the spectral response of bare soils and more particularly sand. This makes it difficult to monitor the phenomenon of change over time in regions where the vegetation cover is low compared to bare soil. However, its use gives good results when the vegetation has good coverage for selected zone. It is important to note that the vegetation index and the gloss index in an international project (GIS-STEPPE) have been applied to the Aflou region. The results were satisfactory and the areas of change were easily identified [12].

The dynamic land cover index is obtained from a subtraction made respectively on the two ETS+3 and TM3 channels of Landsat for the period from 1987 to 2002. In this index, the progression of mineralized spaces is represented by the high values, on the other hand, the progression of green spaces is coded by low values. In addition, in the red channel the phenomenon of vegetation variation during the seasons remains stable.

For the visualization of the dynamic index of land cover a color scale which ranges from dark level to saturated red were

respectively passing through blue, cyan, green and yellow has been applied. Also, the progression and regeneration of the vegetation occupy the low values of IDCS and takes on the black and purple color. However, the total absence of vegetation (mineral progression) is manifested by shades of IDCS colors from saturated red to yellow green. As for the unchanged zones, they appear in blue and cyan. On the basis of this color palette, a thresholding on IDCS was carried out. The radiometric values were grouped and coded according to three different classes (Table 6).

Table 6: Classification and coding of the radiometric values of the IDCS diachronic image between 1987 and 2002.

Colour class	Class type	Value class	Code
From purple to black	Vegetable progression	[0,1510-0,0837]	1
From cyan to blue	No change	[0,0838-0,1557]	2
From saturated red to yellow	Mineral progression	[0,1558-0,5809]	3

The classification of the IDCS into three classes allowed doing a link between the state of the vegetation and the type of change which affected the study area from 1987 to 2002. The mineral progression is linked to a degradation of the condition of the vegetation and the progress of the silting up. On the other hand, the increase in vegetation is a sign of progressive variation. The unchanged radiometry corresponds to the relatively stable zones.

In Figure 6, the development zone of Ain Benkhilile appears as significant plant growth from 1987. However, the north-west and south-west zones experienced a significant mineral progression which affected the areas of encrusted glacis and with limestone encrusting from the Hafid, Bou Khachba and Guetob el Hamara djebels.

As for the southwest area, the mineral progression is certainly linked to the instability of the dune cordon located in the northwest flank of the Gaaloul, Erreha, Arar, Kerrouch and Bou Amoud djebels. This dune cord is fed by the large source of sand supply located in the Chig Tigri located in the Moroccan territory.

The gradual changes of the mineralized zones are dominant in this figure compared to the gradual changes of the vegetated zones. The latter are due to market gardening practices and the presence of vegetation along the wadis, as is the case along the Timedmaket wadi (Figures 3-5). The site (2) located south of Lake Ogalt ed Daïra corresponds to reforestation work at the base of *Tamarix gallica* to protect the wetland of the lake. Likewise, zone (5) concerns reforestation on the southern flank of Djebel Antar for the protection of areas downstream against water erosion. These reforestation works, which are part of the fight against desertification, are carried out by the forest management. Finally the plant progression in (6) is due to the presence of the wetland of Oglat in Nadja. Apart from these

areas of plant growth, we note the total absence of herbaceous and woody species.

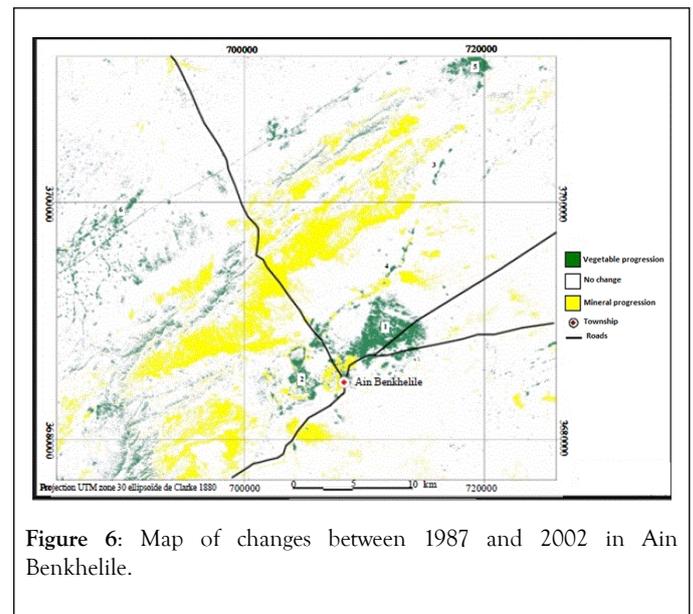


Figure 6: Map of changes between 1987 and 2002 in Ain Benkhilile.

Figure 7 shows the changes in the surface condition in the Faidjet el Betoum area located southeast of the Ain Benkhilile area compared to the previous area, the interpretation of this area is quite delicate. Within it wetlands are classified as plant growth. Indeed, these wetlands are represented by low values in the red channel in the same way as vegetation. Therefore, if one of the two multi-date scenes (1987-2002) is taken during a wet year, the image of changes may present sites in plant growth, but in reality these have no link with the rise natural vegetation or dry or irrigated crop areas. This is the case of the sites (Figure 6) which are classified as areas of improvement from 1987. But in reality these areas correspond to areas of depression (Haoud ed Derba, Haoudcherkat) and spreading wadis. The progression of the El Magroune dune cordon (Figures 4-6) from 1987 is clearly visible in the image. This progression follows a south-west north-east direction. Faced with this situation, an investigation work in the field as well as also photo-interpretation work was carried out on the two colored compositions of the two dates in order to overcome the difficulties were undertaken.

The increase in plant cover in zones 5 and 6 in Figure 6 illustrates the biological uplift of vegetation in mountainous zones. This progression concerns the areas of Jebel Aissa (6) and Jebel Morhad (5) of the city of Ainsefra. These have benefited from rehabilitation works and the creation of green strips plus the strengthening of forest structures. Indeed, Djebel Aissa has been classified as a National Park since February 1992 [2]. However, the glacis zones experience a continuous and severe degradation by the grubbing and uprooting of steppe vegetation, and the increase of the pastoral load in these places close to the National Road (RN6).

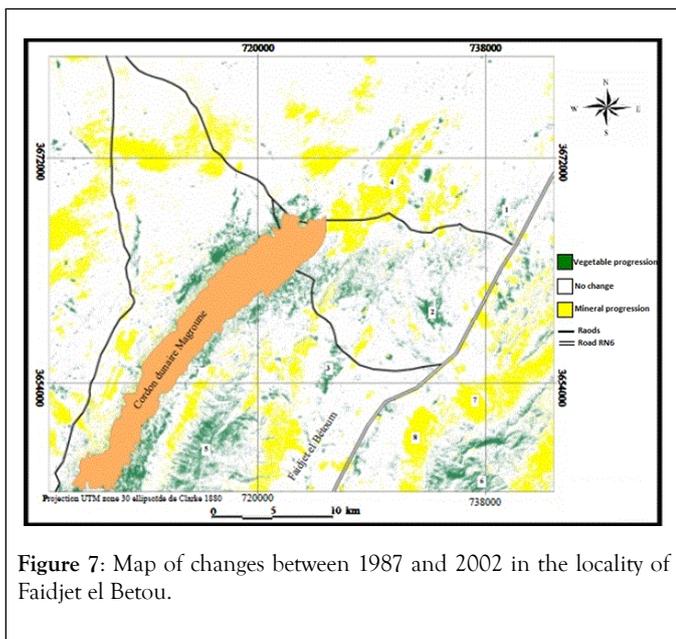


Figure 7: Map of changes between 1987 and 2002 in the locality of Faidjet el Betou.

RESULTS AND DISCUSSION

The use of remote sensing data through the dynamic soil cover index and the diachronic color composition made it possible to highlight the various changes that took place from 1987 to 2002. These changes concerning the mutations of landscape units in the steppe zone, it was necessary to test several indices of change (vegetation index, gloss index, curasse index and principal component analysis) in order to minimize errors in the assessment of the results on the changes. It is important to know that in remote sensing the result of dynamic changes is influenced by cyclical variations (season, weather conditions). Hence the need to apply radiometric and atmospheric corrections to the images. Within the framework of this study, the accent was put on the processing of data of diachronic remote sensing for the follow-up and the evolution of the silting up in an arid environment concerning the south-western part of the high plains of Oran. The difference made on the two red channels of the images during the period from 1987 to 2002 made it possible to obtain the map of changes. The result of the difference between the two channels is a picture of the changes in the study area. The histogram values for this image have been grouped into three classes according to the types of change (Table 7).

Type of change	Area in hectare	Area in (%)
Vegetable progression	287129,89	9,63
No change	2249365,79	75,43
Mineral progression	445627,48	14,94

Analysis of the change map for the entire area showed the impact of sand progression within the areas of the Naâma willaya (Figure 8). However, this did not prevent the existence of certain areas for improvement (biological uplift of vegetation), in particular mountain areas and areas that have experienced

restoration and reforestation works. From the interpretation of the change map (1987-2002) we noted that the most convincing mutations in the surface state mainly affect the steppe vegetation and the sandy accumulations. In fact, in 1987 the plant cover showed a certain gradation from north to south and from west to east.

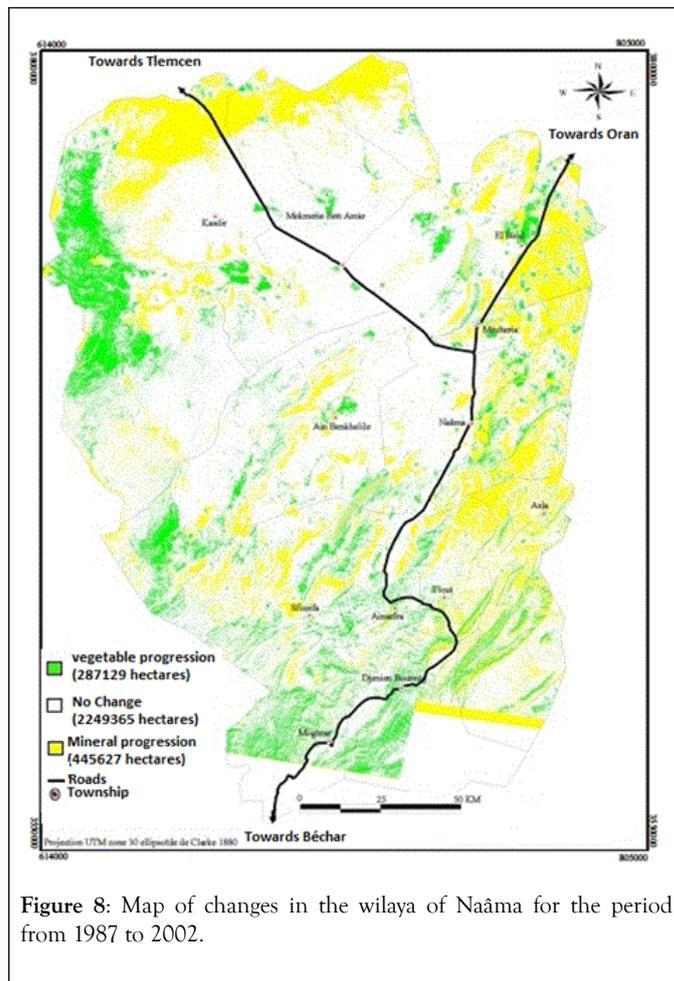


Figure 8: Map of changes in the wilaya of Naâma for the period from 1987 to 2002.

CONCLUSIONS

The use of Landsat images MSS, TM and ETM+allowed following the spatiotemporal evolution of the dynamics and the mutation of the steppe area on a regional scale and more particularly the phenomenon of silting in the wilaya of Naâma over a period of 45 years. The cartographic document topographic maps at 1:200,000 scales from 1957 have been taken as a reference. It is important to note that no cartographic document, apart from the testimony of elderly people (field survey carried out in December 2004 with the team from the geographic space Laboratory and spatial planning laboratory (University of Es-senia, Oran, Algeria) and archival documents were not found for the study area before the date of 1957. It would be very beneficial to have available old documents to fully understand the evolution of the phenomenon of silting up.

It is important to note that the diachronic study involved delicate phases, in particular the choice of the mathematical model for the atmospheric correction (absolute or relative) of the satellite images as well as the determination of the parameter of the real reflectance of the soil for the test samples. This

parameter requires adequate equipment (spectroradiometer) or a database on the absolute reflectance of objects. Similarly, in this study it turned out that the indices (vegetation index, gloss index, breastplate index) are not very effective for detecting change in an arid zone where the characteristics of the soil and the presence of sand influence considerably the spectral aspect of the objects.

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